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Breeding methods to reduce abiotic stress in ornamental crops due to climate change: An overview

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Abstract

In many parts of India, abiotic stress is a major problem that has an especially negative effect on agricultural areas. Extremely low and high temperatures, protracted dryness, and increased soil salinity are the causes of this problem. Crop growth is significantly hampered and their production is reduced as a result of the combination of these conditions. However, there have only been a few initiatives made to solve this issue, particularly in the context of decorative crops.

Soil salinity stands out as a significant contributor to the many stress factors, adversely affecting the general growth and expansion of plants. Decorative crops now have the potential to earn more money than other crops and contribute significantly to the growth of the national economy. Breeding ornamentals that can survive in difficult conditions is today's problem. There are several ways to deal with abiotic stress, but only a small number of them have been shown successful for attractive crops. The transfer of abiotic stress-resistant traits from cultivated varieties to their wild counterparts through extensive crossbreeding methods, including both interspecific and intergeneric hybridization, has demonstrated promise in improving the drought tolerance of various crops. In vitro mutagenesis is a crucial tactic that integrates tissue culture approaches with induced mutation techniques. It is another important tool. This novel strategy has the potential to improve crop plants' overall quality and productivity while also boosting their resistance to diverse stresses. In the context of ornamental crops, introducing novel traits by traditional breeding techniques—such as distinctive hues and improved abiotic stress resilience—often poses significant challenges. However, a quicker method of reaching these objectives is through genetic modification. This work focuses on a thorough investigation of the literature on holistic plant breeding methods designed to improve abiotic stress resistance in ornamental crops. In particular, the study explores the subtleties of breeding techniques that handle the difficulties brought on by extreme temperature changes, drought, and salinity stress. It is significant to note that the thorough examination of breeding strategies in response to these particular stresses is beyond the purview of this review.

Keywords: Abiotic stress, ornamental flowers, genetic engineering, hybridization

Introduction

The genotype, environment, and genotype-environment interaction all affect a plant's phenotypic performance. Stress occurs when an environmental condition prevents a person's genotype from fully expressing itself. Depending on their biological makeup, stress can also be divided into biotic (pathogens, pests, weeds, etc.) and abiotic categories. Moisture, temperature, minerals, salinity, soil pH, air pollution, and other abiotic factors cause stressors. Conditions of abiotic stress result in significant losses to global agricultural productivity. Individually, stress factors like heat, salinity, and drought have been the focus of extensive study. However, in the field, various abiotic stresses are frequently combined to regularly subject crops and plants to them. For instance, many crops in drought-stricken areas experience both drought and other pressures at the same time.

Abiotic stress characteristics

- Depending on the environment, abiotic stress characteristics might vary greatly.
- The relative weighting of various abiotic stresses varies greatly depending on the environment.
- During the crop season, the intensity of some pressures is likely to change.
- In a saline soil, moisture stress would exacerbate salinity stress. - A particular abiotic component may increase/decrease the level of another abiotic stress.
- The capacity of various plant/crop species to tolerate a particular stress varies noticeably.
- Crop types differ significantly in their capacity to withstand abiotic stressors.
- Some of the effects produced by one abiotic stress may also be produced by another.
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Drought

A region experiences drought when the weather is exceptionally dry and there is not enough precipitation in the area. It is controlled by a number of variables, including temperature extremes, photon irradiance, and water scarcity. Due to the high solute content, the water potential is low.

Mechanism for Tolerance to Drought

Drought escape

It is described as a plant's capacity to finish its life cycle before the soil's source of water runs out and to produce dormant seeds before the start of the dry season. Due to their quick development, these plants are referred to as drought escapers.

Drought avoidance

In spite of low soil moisture, plants have the capacity to maintain relatively high tissue water potential. The maintenance of turgor by deeper root growth in the soil, stomatal control of transpiration, and decrease of water loss through reduced epidermal, or reduced surface, by smaller and thicker leaves are all ways to resist drought.

Drought tolerance

It is the capacity to resist low tissue water potential and water deprivation.

Impact of Drought Stress

- Impact on Nitrogen Metabolism: Nitrite reductase activity is not impacted by a drop in nitrate reductase activity.
- Effect on carbohydrate metabolism: Starch is lost, simple sugars are acquired, and carbohydrate translocation is decreased.
- Impact on Growth: Decreased cell diameters result in lower turgor pressure, which has an impact on the plant's general growth.
- Impact on Photosynthesis: Under drought stress, Photo System II (PS II) is disrupted, stomata close, and electron transport is reduced, all of which together lead to a fall in photosynthetic activity.
- Changes to Nucleic Acids and Proteins: Plants under drought stress see a drop in their levels of nucleic acids and proteins. Protease activity is subsequently raised as a result of this decrease.

Salt stress

"Salt stress is caused by too much salt in the soil, which stunts plant growth and ultimately causes crop death. In plants under salt stress, stem extension is inhibited, ions are increased, heat stress is caused, and water consumption efficiency decreases.

The buildup of free ions initiates the breakdown of biological macromolecules. Plants under salt stress were shown to produce less hydrogen peroxide, have different electrolyte levels, and had less water in their cells [3]. Notably, the buildup of salts in soil constitutes a serious problem, resulting in decreased plant quality and output. This phenomenon has a negative impact on a variety of activities, including germination, plant growth, and general development. More than 45 million hectares of irrigated agricultural land are affected by salt stress.

Ornamental plants exhibit multifaceted reactions in response to salt stress

When exposed to salt stress, ornamental plants react in complex ways that involve interactions between physiological, biochemical, and morphological processes. According to studies [5], the reduced rate of leaf growth is an early and obvious plant response to salt stress among the range of repercussions that result.

The osmotic effect of salts surrounding the plants is principally responsible for how salt stress affects attractive plants. Water supply to leaf cells is consequently reduced as a result of the roots. The growth of roots can also be hampered by high salt concentrations in the soil [6], which can reduce root length, total mass, and functional capacity [7]. Reduced rates of cell elongation and division in leaves are linked to this root development inhibition, which reduces the size of the leaves overall and their ultimate size [8, 9]. This decrease in leaf area can be linked to a decline in photosynthesis, a change in the properties of the cell wall, or a decrease in the turgor of the leaves. Plants used as ornaments are in fact vulnerable to these problems. According to Cassaniti *et al.* [10], regardless of whether the species is sensitive or resistant, the early observable effects of salt stress include a reduction in shoot dry weight and leaf area. This behavior has been observed in species like Eugenia myrtifolia, which is tolerant, and Cotoneaster lacteus, which is sensitive. In addition, thickening of leaves, a reaction seen in ornamental plants like Coleus blumei and Salvia splendens [11], is another frequent result of high salt concentrations.

Heat stress

Heat stress occurs when temperatures surpass a critical threshold and endure for a duration that leads to enduring negative impacts on plant growth and development. Elevated temperatures beyond the optimal range can induce heat stress in plants. Heat significantly influences a plant's survival, growth, developmental trajectory, and physiological functions. The nature and severity of these effects are primarily determined by the temperature level, the plant species, and the specific physiological processes involved. Heat stress is characterized by a sustained elevation in temperature that leads to irreversible damage to plant growth and development [12]. Throughout its life cycle, heat stress affects a plant's growth, although the specific heat The importance of threshold varies significantly depending on the experimental stage. Global crop output is severely hampered by elevated temperatures brought on by high ambient temperatures. According to projections from many global circulation models, greenhouse gas emissions are to blame for the slow rise in the average world temperature. Rapid and extreme heat stress can seriously injure cells, even resulting in cell death in a short amount of time. Direct effects at relatively high temperatures include increased fluidity of membrane lipids and protein aggregation and breakdown. In addition to inactivating enzymes, heat stress also inhibits protein folding, causes protein breakdown, and compromises the integrity of membranes.

Cold stress

Abiotic cold stress has a negative impact on plant growth and agricultural productivity. It includes both cold (between 0 and 15 °C) and cold (below 0 °C) circumstances. Plant growth is frequently hampered by cooling stress, and It causes a wide range of notable actions on plant cells that are important for growth. Cold stress poses a serious threat to the viability of agricultural production and can result in large crop losses. The phenotypic signs of cold stress in plants can take many different forms, including as insufficient germination, stifled seedling development, yellowing of the leaves, constrained leaf expansion, wilting, and, under extreme circumstances, tissue death or necrosis. Plant reproductive system development is significantly impacted by cold stress. The severe harm that cold stress causes to plant cell membranes is one of its most harmful effects. chilling or chilly Stress often happens in the 0 to 15 °C temperature range. In reaction to these circumstances, plants work to preserve internal harmony in an effort to promote freezing tolerance. This endeavor necessitates significant changes in gene expression and metabolic functions, which results in a reprogramming process [13, 14].

Methods to breed for increased abiotic stress tolerance

Wide- distant hybridization

Wide-distant hybridization, which includes both interspecific (between species) and intergeneric (between genera) crossings, has a great deal of potential to improve a crop's ability to survive abiotic stress. In order to take advantage of the better abiotic stress tolerance frequently present in wild relatives that cultivated varieties lack, this strategy includes introducing stress-tolerant characteristics from closely related wild species into cultivated varieties [15, 16]. For instance, a drought-tolerant variation was created via the intergeneric hybridization of perennial ryegrass (Lolium perenne) with Atlas fescue (Festuca mairei), which inherited drought resistance from the wild species [17]. Similar to this, interspecific hybridization has produced numerous cultivars of drought-resistant Chrysanthemum [18]. Techniques for ovary rescue were used to create interspecific hybrids.

In vitro mutagenesis

A key method for increasing crop plants' ability to endure stress as well as their output and quality is in vitro mutagenesis. In vitro mutagenesis is a hybrid approach that combines techniques for induced mutation with those used in tissue culture. In a famous use of this strategy, ethyl methane sulfonate (EMS) was used as a chemical mutagen to establish a NaCl-tolerant variety of chrysanthemum (Chrysanthemum morifolium Ramat.). With the help of this method, the plant developed persistent mutations that increased its tolerance to salt stress. Even under stressful circumstances, the created Chrysanthemum variety showed endurance in retaining bloom quality and output. Multiple variables were responsible for the E2 variety's improved tolerance.

An important role was played by the enhanced activity of certain enzymes, including superoxide dismutase (SOD), ascorbate peroxidase (APX), and dehydroascorbate reductase (DHAR). Enzymes play a role in the control of oxidative stress. The E2 variety also shown lower levels of membrane deterioration in comparison to the NaCl-treated control plants, which added to its increased salt tolerance. The Cu/Zn isoform was significantly activated, according to isoform analysis, and this was the main contributor to the total increase in superoxide dismutase (SOD) activity in the E2 variation. A higher free radical scavenging capacity (RSC), measured by DPPH (diphenyl-1 picrylhydrazyl) scavenging ability, was detected in E2 leaves, which corresponded to higher amounts of carotenoids and ascorbate. For Chrysanthemum to effectively mitigate salt stress, it is crucial to maintain a suitable balance between enzymatic and non-enzymatic defense systems. Notably, the E2 variety performed better under the identical salt stress circumstances, further demonstrating its innate tolerance. It is supported by the persistence of salt tolerance features across time that E2 is thought to have inherited salt tolerance traits.

In conclusion, the 0.025 EMS treatment resulted in the E2 variety, which can be characterized as a NaCl-tolerant strain with beneficial features for withstanding salt stress [20].

Genetic modification to enhance abiotic stress tolerance

Plant types that display strong resistance to abiotic stresses must be developed in order to produce the highest yield possible and to guarantee production stability. Due to the complexity of abiotic stress variables and their complex genetic regulation, traditional breeding techniques aiming at improving abiotic stress tolerance have encountered major difficulties.

The complexity of abiotic stress and the inherent challenges in identifying and choosing pertinent features lead to the limits of conventional techniques. As opposed to conventional breeding techniques, genetic engineering offers a more effective approach by inserting certain, desirable genes into crops, resulting in faster development times. Genetic engineering, as opposed to conventional breeding, enables the exact transfer of only the desired genes, hence reducing the danger of unintended gene transfers. To successfully use genetic engineering, it is essential to comprehend the genetic pathways driving stress tolerance. The basis for integrating stress-tolerance genes into crops and producing varieties that can resist tough environmental circumstances is laid by the identification of these critical genes and regulatory mechanisms. Recent developments in cellular and molecular biology have made it easier to clone and transfer vital genes across different organisms. These genes can be transmitted and expressed consistently across species barriers in a variety of organisms. This discovery frees researchers from the constraints of sexual hybridization and gives them a potent tool to create crops that can withstand stress.

In summary, increasing yield potential and stabilizing production depend greatly on the development of plant types with enhanced abiotic stress resistance.

The promise of genetic engineering is the effective introduction of stress-tolerance genes into crops to produce robust and resilient cultivars. Genetic engineering is driven by advances in genetic understanding and molecular technology. Across the board, organisms have developed defences against or adapt to abiotic stressors. In particular, plants that synthesize vital enzymes or proteins from other organisms, crucial to abiotic stress tolerance systems, have shown a notable advantage over their wild type counterparts in difficult environmental conditions.adding additional osmolytes and radical scavengers. The best possible deployment of these durable transgenic features is being worked on. This includes the thoughtful distribution of advantageous goods like osmolytes and radical scavengers, which can protect plants from abiotic stressors. A thorough knowledge of the molecular complexities of stress detection, signal transduction, and response mechanisms in both plants and other species is essential to achieving greater tolerance to a variety of stressors. The effectiveness of inheritable engineering for abiotic stress tolerance is being actively supported by novel approaches and concepts. The necessity to generate plants with strong resilience to various stressors is what motivates this pursuit. It is anticipated that new strategies will emerge as researchers delve deeper into the molecular basis of stress reactions, resulting in the development of crops that are especially well-equipped to flourish under difficult environmental conditions [22].

Conclusion

Abiotic stress is a key barrier to the best crop development and yield since it results from elements like temperature changes, drought, or salinity. Several breeding approaches have proven effective in boosting ornamental crops' resistance to these difficulties. These include genetic engineering, in vitro mutagenesis, and interspecific and intergeneric hybridization. Genetic material from related species or genera is merged through interspecific and intergeneric hybridization to introduce desired features such abiotic stress tolerance. In vitro mutagenesis is the process of creating genetic changes under controlled conditions to create new variations with increased stress resistance. By introducing unique traits that aren't naturally present in the organism, genetic engineering goes one step further and improves the organism's ability to withstand abiotic stimuli. When it comes to genetic engineering, the addition of foreign genes or the modification of already existing genes can bestow new capacities to counteract abiotic stress. Specific enzymes, proteins, or other substances that improve the stress tolerance processes in ornamental crops may be encoded by these newly inserted genes. In conclusion, abiotic stress seriously hinders crop growth and output, even for ornamental cultivars. Breeding strategies like genetic engineering, mutagenesis, and hybridization present exciting opportunities for improving abiotic stress resistance. In particular, genetic engineering makes it possible to introduce unique traits that can help ornamental crops better survive the difficulties posed by abiotic stresses.

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